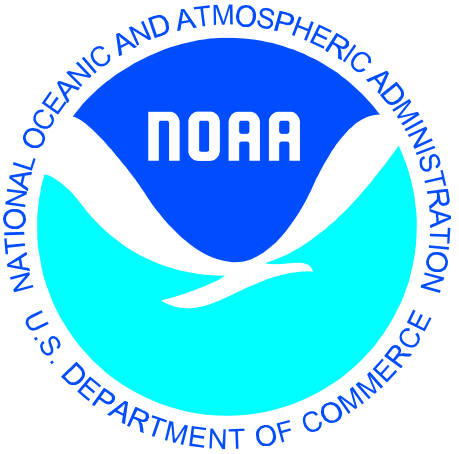
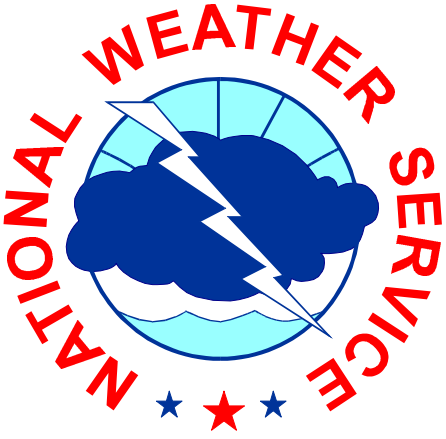
1999 NWS Field Assessment of GOES Sounder Products

Final Report





March 31, 2000

Results from the 1999 NWS Field Assessment of GOES Sounder Products

Executive Summary:

The NWS Office of Meteorology conducted an assessment of GOES-8 and GOES-10 Sounder products from July 19 through August 30, 1999. The purpose of the evaluation was to assess the operational value of the GOES Sounder products to the NWS Forecast and Warning Program. Participants were asked to comment on their use of sounder data following each forecast shift. 37 NWS forecast offices, 4 national centers, and NESDIS Satellite Analysis Branch participated in the evaluation, providing a total of 638 responses (635 via a web based questionnaire).

Forecasters used the sounder products to help evaluate the threat of a variety of weather phenomena, including tornados, severe thunderstorms, monsoon precipitation, and flash floods. **Participants indicated the use of the GOES Sounder products heightened their situational awareness to potential watch/warning scenarios.** Their responses showed that **in over 79% of all active weather situations, the use of GOES Sounder products led to the issuance of improved forecast products.**

An evaluation of the use of GOES Sounder data or derived products for Numerical Weather Prediction was not conducted and is not discussed in this report.

Overall, forecasters found the sounder products to be valuable operational tools, providing information on the vertical structure of the atmosphere, especially the moisture distribution, with a temporal and spatial resolution not available from any other source. They provided numerous specific examples of forecasts that were improved based on the use of GOES Sounder data. Case studies demonstrating the operational use of GOES Sounder products are being finalized. We will append selected cases to this report in the summer of 2000. The following report presents the details of the 1999 Sounder Assessment including a breakdown of the responses to the web-based questionnaire, and brief descriptions of actual forecast applications of the sounder products.

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Results from the 1999 NWS Field Assessment of GOES Sounder Products

Introduction:

This assessment was conducted to determine the potential utility of GOES Sounder products in improving operational forecast products and services at NWS forecast offices and national centers. The assessment ran from 1200 UTC, July 19, 1999 until 1200 UTC, August 30, 1999. This time frame was selected to evaluate the value of GOES Sounder products during the monsoon season across the southwest U.S., general convection throughout the country, and any tropical weather events which might occur.

The following GOES Sounder Derived Product Imagery (DPI) were included in the assessment: Atmospheric (In)Stability: Lifted Index (LI), Convective Inhibition (CINH), Convective Available Potential Energy (CAPE); Moisture: Total Precipitable Water (TPW); Temperature: Skin Temperature (ST); and Clouds: Cloud Top Pressure (CTP). GOES derived vertical profiles of temperature and dewpoint were also assessed.

Although not formally part of the assessment, a few NWS sites also evaluated NESDIS' Wind Index (WINDEX) DPI (a measure of potential microburst/downburst winds). Feedback on this product was relayed to appropriate NESDIS personnel.

Background:

The current GOES Sounder has 19 (1 VIS and 18 IR) channels. GOES Sounder field of view (FOV) resolution is approximately 10-km. Soundings are generated in cloud-free areas at a 30-km spacing. Between 2,000 and 3,000 soundings are made each hour from both GOES-East and GOES-West.

Although the current GOES Sounder cannot "see" through clouds it's greatest utility is for events/times prior to the onset of convection or areas adjacent to convection. The hourly DPI are most useful identifying time change or trends and axes/gradients of (in)stability, moisture, and temperature.

The hourly GOES soundings and DPI use NCEP model data as a "first guess" (initial conditions). The 6-18 hour model forecast are used (e.g., the DD/12Z model data is used for DD/18Z - DD+01/06Z). For the last several years, NESDIS has used NCEP's ETA model for the first guess. Effective October 7, 1999, NESDIS' Forecast Products Development Team (FPDT) switched to the AVN model as the first guess for GOES soundings and sounder DPI. FPDT expects this change will improve the accuracy of the GOES soundings/DPI by approximately 5-10%. **NOTE: Assessment results presented here represent forecasters' evaluation of the GOES Sounder data/products using the ETA as the first guess.**

Data Acquisition/Assessment Methodology:

Because of the sounders' geographic coverage, selected national centers and the four CONUS NWS regions were the primary participants in this assessment. The Pacific Region, however, was able to evaluate TPW data in a very limited fashion because the GOES-10 Sounder

scans much of the northeast Pacific. A Numerical Weather Prediction sounder assessment was not conducted, however, three layers of moisture retrieved from the GOES Sounders were used in the operational ETA model during the assessment period.

Some WFOs equipped with AWIPS obtained the GOES Sounder data through Local Data Acquisition and Dissemination (LDAD). However, at non-AWIPS sites, or AWIPS sites where LDAD was not yet operational, sounder data was primarily accessed over the SOO/SAC work station (or other PC with Internet capability).

URLs for web sites where near real-time GOES Sounder data was available were readily accessible via hyper-text links from a specially designed GOES Sounder Assessment Web Page. WFO and national center forecasters assessed GOES Sounder data (DPI and sounding profiles) as they pertained to their daily forecast operations. Virtually all results were reported via the Internet. Evaluators submitted their results during each forecast shift.

Summary of Participation:

37 NWS Forecast Offices, the Marine Prediction Center (MPC), and NESDIS Satellite Analysis Branch (SAB) submitted a total of 635 web-based responses. Aviation Weather Center, Hydrometeorological Prediction Center, and Storm Prediction Center each provided one written response. The following table reflects the number of all NWS and NESDIS web-based responses from each participating location:

Aberdeen, SD (ABR) - 30
Albuquerque, NM (ABQ) - 9
Amarillo, TX (AMA) - 15
Austin/San Antonio, TX (EWX) - 24
Binghamton, NY (BGM) - 9
Birmingham, AL (BMX) -11
Boise, ID (BOI) - 4
Charleston, WV (RLX) - 5
Chicago, IL (LOT) - 56
Columbia, SC (CAE) - 12
Des Moines, IA (DMX) - 62
Elko, NV (LKN) - 9
Eureka, CA (EKA) -30
Grand Junction, CO (GJT) - 36
Goodland, KS (GLD) - 13
Grand Rapids, MI (GRR) - 37
Great Falls, MT (TFX) - 1
Honolulu, HI (HFO) - 3
Key West, FL (EYW) - 3
Las Vegas, NV (VEF) - 2
Los Angeles, CA (LOX) - 5
Miami, FL (MFL) - 3
Marine Prediction Center (MPC)[1] - 49
Minneapolis, MN (MPX) - 24
Missoula, MT (MSO) - 6
Northern Indiana, IN (IWX) - 44
Omaha, NE (OAX) - 46
Pendleton, OR (PDT) - 1
Pocatello/Idaho Falls, ID (PIH) - 1
Portland, OR (PQR) - 9
Pueblo, CO (PUB) - 4
Reno, NV (REV) - 3
Roanoke, VA (RNK) - 25
Sacramento, CA (STO) - 11
Salt Lake City, UT (SLC) - 16
San Francisco, CA (MTR) - 1
Satellite Analysis Branch (SAB)[2] - 3
Spokane, WA (OTX) - 1
Tallahassee, FL (TAE) - 11

[1] Located at National Centers for Environmental Prediction, NOAA Science Center (NSC), Camp Springs, MD
[2] Located at National Environmental Satellite Data and Information Service, NSC, Camp Springs, MD

Results:

Web-Based Survey: Participants were asked to characterize the predominant weather situation into one of several categories. A breakout on total responses (635) for each follows:

No significant Weather - 307 (48.4%)
Convection Anticipated - 218 (34.3%)
Monsoon Precipitation - 37 (5.8%)
Other - 34 (5.4%)
Severe Thunderstorm Watch/Warning - 21 (3.3%)
Flash Flood Watch/Warning - 16 (2.5%)
Tornado Warning - 2 (0.3%)

Answers to Specific Questions:

Did the GOES Sounder Products increase your confidence convection would/would not develop? (250 weather cases)

Yes - 188 (75.2%) No - 62 (24.8%)

A follow-on question asked the forecasters who specified yes, above, to prioritize which GOES Sounder products made the biggest positive difference in their confidence convection would/would not develop? In priority order (top-to-bottom) are those results:

Lifted Index (LI)
Convective Available Potential Energy (CAPE)
Total Precipitable Water (TPW)
Sounding Profiles
Convective Inhibition (CINH)

Rate the usefulness of the Total Precipitable Water product (changes in time/axes/gradients of moisture in the hourly product) to your precipitation forecasting program (select one): (207 weather cases)

Significant Positive Impact - 44 (21.3%)
Slight Positive Impact - 104 (50.2%)
No Discernable Impact - 56 (27.0%)
Slight Negative Impact - 2 (1.0%)
Significant Negative Impact - 1 (0.5%)

Rate the usefulness of the Total Precipitable Water product (changes in time/axes/gradients of moisture in the hourly product) to location/timing of thunderstorm activity (select one): (213 weather cases)

Significant Positive Impact - 31 (14.6%)
Slight Positive Impact - 105 (49.3%)
No Discernable Impact - 74 (34.7%)
Slight Negative Impact - 2 (0.9%)
Significant Negative Impact - 1 (0.5%)

Rate the usefulness of (in)stability DPI products (e.g., LI, CAPE, and CINH) (changes in time/axes/gradients in the hourly product) to location/timing of thunderstorm activity (select one): (248 weather cases)

Significant Positive Impact - 74 (29.8%)
Slight Positive Impact - 122 (49.2%)
No Discernable Impact - 47 (19.0%)
Slight Negative Impact - 5 (2.0%)
Significant Negative Impact - 0 (0.0%)

During your shift how much of an impact did the GOES sounding profile and DPI products make relative to available hourly model (ETA/RUC) data to your program(s) and services? (select one) (218 weather cases)

Significant Positive Impact - 56 (25.7%)
Slight Positive Impact - 117 (53.7%)
No Discernable Impact - 44 (20.2%)
Slight Negative Impact - 1 (0.4%)
Significant Negative Impact - 0 (0.0%)

For the next two questions forecasters were asked to assess the Skin Temperature (ST) product. {The ST depicts areal surface heating and cooling rates. It is the temperature of the skin (e.g., soil, vegetation, asphalt, forest canopy, etc.) versus standard air temperature.} The number of cases is indicated for both.

Did the ST product help you modify your temperature (max/min/etc.) forecast? (74 cases)

Yes - 15 (20.3%) No - 59 (79.7%)

Rate the usefulness of the ST product in forecasting convective development (e.g., helping to identify temperature differences in areas where rain has fallen, major vegetation differences, etc.) (76 valid cases)

Significant Positive Impact - 2 (2.6%)
Slight Positive Impact - 23 (30.3%)
No Discernable Impact - 50 (65.8%)
Slight Negative Impact - 1 (1.3%)

Forecaster Comments over the Web: Numerous instances of the GOES Sounder's utility were cited. Several of the more note-worthy responses follow below.

- **Tornado Warning** (8/9 - Minneapolis, MN): " The Sounder Derived Product Imagery (DPI) helped a lot anticipating convective development over southern MN this evening. I looked through the DPI's over a few hours and saw a definite decreasing trend in the CINH (Convective Inhibition) from 19-21Z. It was only a matter of time before the convection fired into southern MN. Impressive CAPE values (3500-4500J/KG) and LI's -10 to -12 pointed to the possible severity of the convection. We received many reports of funnels/brief tornado touchdowns

across south central MN as the convection went through. ...These products overlayed on surface maps/satellite/radar displays on AWIPS would be invaluable to the mesoscale forecaster."

- **Severe Thunderstorm Warning** (7/24 - Grand Rapids, MI): "The WINDEX Derived Product Imagery...proved very useful in determining the microburst potential."

- **Severe Thunderstorm Warning** (8/5 - Portland, OR): "Looked at Lifted Indices dropping very low...also looked at sounding profiles and SWEAT index."

- **Flash Flood Warning** (7/20 - Grand Junction, CO): "Edge of cloud shield revealed significantly higher Total Precipitable Water (TPW) values over the southeast portion of our CWFA. Based on (the TPW) and back-building thunderstorms with heavy rain over southeast portion of the CWFA indicated by radar...issued FFW."

- **Flash Flood Watch** (7/26 - Salt Lake City, UT): "The TPW product clearly identified the ETA model was handling the moisture over AZ and UT much better than the AVN. The AVN's PW analysis was as much as 50% off the actual over extreme southern NV at 00Z this evening while the ETA was nearly right on. This prompted the issuance of an SPS for Flash Flood potential over southern UT. For aviation purposes we included lower ceilings and more thunderstorm activity for the southwest corner of UT due to high TPW values."

- **Monsoon Precipitation** (7/25 - Grand Junction, CO): "...had an isolated thunderstorm develop over higher terrain in an area where (the) previous hour's data showed considerable Convective Inhibition (CINH) (value near -150J/KG). The next sounder-derived CINH image showed a significantly lower value of -34J/KG adjacent to where the storm developed. ...this surprised me because I thought development would occur later over this area."

- **Monsoon Precipitation** (8/1 - Boise, ID): "GOES sounding profiles were used to determine the upstream airmass was significantly more moist than the ETA model indicated...allowing a confident forecast of increased clouds and higher morning minimum temperatures when the airmass reached our CWFA. More clouds than the model implied occurred with resultant higher morning minimum temperatures. Morning temperature forecasts and TAFs were improved using the sounder 12-24 hours before the period of concern."

- **Convection Anticipated** (8/1 - Portland, OR): "Sounder data showed increasing instability and highlighted areas where convection would occur before it began."

- **Convection Anticipated** (8/5 - Amarillo, TX): "The GOES Sounding and DPI products indicated that convection would be confined to the eastern sections of the panhandles, which they were. Despite the forecast we had out for more convection in the northwest sections of the panhandles from the midnight shift, the GOES Sounder products were right on target with their prediction."

- **Convection Anticipated** (8/13 - North Webster, IN): "Cold front across Michigan and Illinois was forecast to move southeast across (our) CWA. The ETA and NGM were developing convection east of our CWA despite the fact fropa would occur during the early afternoon. GOES soundings were much more unstable than 13/00Z ETA. (GOES) soundings from near LAF and FWA at 13/12Z and 13/14Z showed CAPES about 1000J/KG higher than the ETA. LI's were also more unstable by about 2-3C. (The) Great Lake (DPI) Sector also confirmed instability in areas ahead of the front that had breaks in the clouds. All this lead to a forecast of scattered afternoon thunderstorms across the CWA. Thunderstorms began firing around 13/18Z and continued across our CWA during the afternoon. Few storm exceeded SVR limits but heavy rain did occur."

- **Convection Anticipated** (8/14 - Salt Lake City, UT): "GOES Sounder TPW indicated approximately .25-.35 of an inch higher TPW than either ETA/AVN 6-hour model forecasts over western Arizona. This additional information helped in the forecast for adding more weather in southern Utah for tonight and Sunday."

- **Convection Anticipated, But Ruled Out** (8/16 - Chicago, IL): "...a front in Iowa showed up clearly with a CU field. (We were) concerned about possible thunderstorms forming in Iowa and then moving into Illinois. ADAP and MSAS showed very unstable (atmospheric conditions) and good moisture convergence. CAPE was 3000-4000 J/KG. (The) most important (tool) was the (GOES Sounder) CINH. It showed values of -70 to -110 J/KG so precipitation was removed from the forecast."

Written Responses: Three NWS National Centers believed the web-based "survey" was better suited to the NWS Forecast Offices so they solicited feedback or generated their own assessment methodology. Results from these centers follow (*status of recommendations follow each item in italics*):

Aviation Weather Center (AWC) (Fred Mosher): Principally focused on the use of the Cloud Top Pressure (CTP) product. For their specific aviation uses, AWC indicated: {NOTE: CTP is planned for operational implementation in AWIPS Build 5.0 (summer 2000)}

1. CTP cloud height units should be converted to feet above sea level. *(AWIPS users will have the capability to display heights in millibars, feet above sea level, etc., locally.)*
2. The stratus cloud heights off the west coast were too high. A strong marine inversion capped these clouds below 900 mb, but the CTP indicated 700-800 mb heights. AWC speculated the CTP processing algorithm either does not have the inversion or is processing from the top down in the conversion of temperature to height. *(NESDIS Office of Research and Applications has taken action to investigate CTP science issues.)*
3. The CTP 100 mb color bands are too coarse. Finer vertical resolution is needed. The higher clouds appear to have the correct heights, but again finer vertical resolution in feet is needed for the determination of convective cloud top heights. *(AWIPS users will have the capability to specify the vertical resolution of the color bands locally.)*
4. Data timeliness is a problem for Convective Sigmet forecasts. The Convective Sigmet forecasts are generated at HH:40-HH:55. Current cloud top heights are needed at these times and the assessment sounder heights were an hour old. *{Background: GOES-East and GOES-West Sounders scan from north to south. Sectors generally take between 20-32 minutes to scan. Processing of the sounder data occurs once the entire sector is scanned. To support a long-standing NWS requirement NESDIS scans the CONUS to generate approximately 1,300 ASOS Satellite Cloud Products each hour needed for the Hourly Weather Roundup. The oceanic areas are scanned during the remaining part of each hour. In the last few years NESDIS has reduced the processing time significantly (now to about 5 minutes). Little improvement in processing time is expected. The most viable solution is to scan the area(s) of interest faster. Update: A 13Fm CO_2 channel is planned for the imager on GOES-M (launch ~ late 2001). If this new imager channel yields enough accuracy to produce the CTP the timeliness problem will*

disappear. If the CTP continues to be generated from the sounder the Advanced Baseline Sounder, scheduled to fly on GOES-Q (launch ~2010-2012), will scan about 3 times faster than the current sounder. This would greatly increase data timeliness too.}

Storm Prediction Center (SPC) (Steven Goss): Comments about the data were incorporated into SPC Mesoscale Discussions (MKCSWOMCD). Forecasters found the sounding profiles useful in data void areas, and during non-sounding times. Other specific comments received were:

1. Precipitable water product needs to be in inches, not millimeters, or else a second product showing PW in inches should be created. *(Total PW is planned for AWIPS Build 5.0; AWIPS functionality will give local users ability to display TPW in either unit.)*
2. Some misunderstanding still exists that the GOES soundings are not pure GOES data, but ETA data which is then modified by GOES data. *{The use of NCEP model data as a "first guess" for GOES soundings is explained in Chapter 3: The GOES Sounder Retrieval Process, Satellite Meteorology: Using the GOES Sounder (1998 COMET Computer Based Learning Module). All NWS offices receive COMET CBLs.}*
3. The forecasters who used the data felt that the data seemed to be fairly representative as far as we could tell, and was useful especially between sounding times to complement other sources of data.

Hydrometeorological Prediction Center (HPC) (Peter Manousos): Only HPC forecasters issuing "short range" products {such as Quantitative Precipitation Forecast (QPF) and surface prognostic charts through 48 hours} were designated as participants in the assessment. Of all GOES Sounder DPI the TPW was significantly favored for short range forecast production at HPC for assessing (1) moisture distribution and change over time, and (2) model initialization of moisture. Lifted Index DPIs and sounding profiles were also found useful, however, skin temperature DPI was never utilized at all. TPW was also used to assess how well models had been initialized as well as estimate moisture distribution over data sparse regions of the American SW during the monsoon of mid August. **HPC's satellite focal point stressed very favorable responses of TPW utility from his center's forecasters were noted during the assessment.** The breakout on the sounder products evaluated by HPC is:

	Lifted Index (LI)	**Sounding Profiles (SP)**	**Total Precipitable Water (TPW)**	***TOTAL***
NUMBER	4	4	24	***32***
% TOTAL	12.5	12.5	75	***100***

In all but five instances the sounder products were used in HPC's preparation of Day One (0-24 hours) precipitation products:

	Lifted Index (LI)	**Sounding Profiles (SP)**	**Total Precipitable Water (TPW)**	***TOTAL***
0-6hr Quantitative Precipitation Forecast (QPF)	0	4	7	***11***
6-12hr QPF	0	0	4	***4***
12-18hr QPF	0	0	2	***2***
18-24hr QPF	0	0	0	***0***
24-30hr QPF	4	0	0	***4***
0-24hr Excessive Rainfall Potential	0	0	7	***7***
0-24hr QPF	0	0	3	***3***
24-48hr QPF	0	0	1	***1***
TOTAL	4	4	24	***32***

<u>Conclusions</u>:

Forecasters used the sounder products to help evaluate the threat of a variety of weather phenomena, including tornados, severe thunderstorms, monsoon precipitation, and flash floods. **Participants indicated the use of the GOES Sounder products heightened their situational awareness to potential watch/warning scenarios.** Their responses showed that **in over 79% of all active weather situations, the use of GOES Sounder products led to the issuance of improved forecast products.**

With a spatial resolution of 10 km and temporal resolution of 1 hour, forecasters found the GOES Sounder products especially valuable for:

* Locating axes of maximum instability prior to convective development;
* Locating axes of atmospheric moisture prior to convective development;
* Observing temporal changes in atmospheric stability and moisture;
* Comparing sounder data to numerical model forecasts for judging model validity;

The primary limitation of IR sounders is their inability to penetrate cloud cover.

Overall, forecasters found the sounder products to be valuable operational tools, providing information on the vertical structure of the atmosphere, especially the moisture distribution, with a temporal and spatial resolution not available from any other source. They provided numerous specific examples of forecasts that were improved based on the use of GOES Sounder data. They requested that GOES Sounder products be operationally available in AWIPS as soon as possible.

The Advanced Baseline Sounder, planned for GOES-Q, would offer a substantial improvement over the present GOES Sounder by: (1) scanning a substantially larger portion of the earth hourly, (2) provide accuracy approaching radiosondes, 3) yield far more detail in the vertical water vapor structure of the atmosphere, and 4) allow for more accurate cloud top properties to be defined. These additional capabilities offer the promise for further improvement in the quality of NWS forecast products.

Acknowledgments: Sincere thanks to all the participants listed on page 2 and to NWS Regional Scientific Services Divisions (SSD) in the Eastern, Central, Southern Regions for their enthusiastic support of this project. We, also, want to recognize the pioneering efforts of Kevin Schrab, WRH/SSD, who established the LDAD capability by which many WFOs could ingest the sounder data into their AWIPS as well as years of work distributing this data via the Internet. More thanks are due to other data producers/distributors: Hank Drahos, Jaime Daniels, and Gary Gray of NESDIS/FPDT; and Tim Schmit, Gary Wade, and Tony Schreiner, ASPT/CIMSS. We want to express our special appreciation to Don Gray, NESDIS GOES Product Manager, for his support throughout the project, and finally to Mike Gerber and T.C. Yang of the Office of Meteorology and Alan Darling of the Office of Systems Operations for their support in setting up the web-based questionnaire and the data bases necessary to archive the several hundred responses.

Abbreviations and Acronyms

AVN	Aviation Forecast Model
AWC	Aviation Weather Center
CAPE	Convective Available Potential Energy
CINH	Convective Inhibition
CONUS	Continental United States
CTP	Cloud Top Pressure
CWA	County Warning Area
CWFA	County Warning Forecast Area
DPI	Derived Product Imagery
ETA	Regional Forecast Model
FOV	Field of View
FPDT	Forecast Products Development Team
FWA	Fort Wayne, Indiana
GOES	Geostationary Operational Environmental Satellite
HPC	Hydrometeorological Prediction Center
LAF	Lafayette, Indiana
LDAD	Local Data Acquisition and Dissemination
LI	Lifted Index
MPC	Marine Prediction Center
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite, Data, and Information Service
NSC	NOAA Science Center
RUC	Rapid Update Cycle (Forecast Model)
SAB	Satellite Analysis Branch
SPS	Special Weather Statement
ST	Skin Temperature
SWEAT	Severe Weather Threat Index
TAF	Terminal Aerodrome Forecast
TPW	Total Precipitable Water
URL	Uniform Resource Locator
WFO	Weather Forecast Office
WINDEX	Wind Index